CELMN-ED-HC 30 Nov 93

MEMORANDUM FOR Chief, Resource Management Office
Attn: Derryl Dossmann

SUBJECT: Suggestion #CELMN920007 - Review of Need for Out-Year Levee Lifts -- Wave Runup

1. We recommend denying the subject suggestion as it pertains to lowering design grades and elimination of out-year levee lifts.

2. We have concluded that a reanalyses of the project, employing latest technology, is prudent and recommend it. Measures to undertake this task are being pursued. This reanalysis will identify project deficiencies and provide information that will enable us to make 'smart' decisions for future maintenance items. We do not recommend or foresee the lowering of existing approved levee grades. The accuracy of results from employing even the latest technology would not support lowering approved levee grades one to two feet when the fate of almost one million people is in question.

COMBE
CELMN-ED-HC

LAURENT
CELMN-ED-H

W. EUGENE TICKNER
Chief, Engineering Division

TICKNER
CELMN-ED

unofficial

CELMN-ED-HC 30 Nov 93

MEMORANDUM FOR Chief, Coastal Engineering Research Center,
3909 Halls Ferry Road, Vicksburg, MS 39180-6199

SUBJECT: Cost Estimates for Model Studies of Lake Pontchartrain

1. The Lake Pontchartrain Hurricane Protection project protects the New Orleans area from storm surges. This project was formulated and designed using hurricane surge technology and methodology of the 1950's and 1960's. The project protects the lives and property of several hundred thousand inhabitants of the coastal flood plain. Its performance must insure protection for events up to and including the Standard Project Hurricane. Thus, Messrs. Combe and Stutts and Ms. Hote of NOD met with Messrs. Leenknecht, Scheffner, and Thompson of your staff regarding the probable effects of using state-of-the-art coastal design methodologies in reanalyzing the project. The reanalysis would be conducted with a view towards insuring that, as a minimum, the authorized degree of protection is uniformly designed and constructed throughout the protection system. The uncertainties associated with datum adjustments occurring since project construction was initiated (1966) and our extensive use of 1 or 2 feet as freeboard for floodwall construction makes accuracy and reliability in storm surge forecast a critical matter. The Lake Pontchartrain Storm Surge Pilot Study conducted last year by your staff and hurricane surge studies conducted in the early 1980's by WES support the need for further anaylsis. A followup meeting was held here at the District to discuss reanalyzing the project based on the potential for loss of life, cost savings, and future maintenance requirements. As a result of these meetings, we are gathering data to use in recommending reanalysis of the project. Because of the magnitude of this effort and the costs, much of this work will have to be approved by Headquarters and our local sponsor.

2. Please provide time and cost estimates for the following tasks:

a. Assist us in developing a 2-D wave generation model for Lakes Pontchartrain and Borgne and teach us to use the model.

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b. Reanalyze surge heights for the Lake Pontchartrain Hurricane Protection Project by developing a 2-D storm surge model of the Gulf of Mexico, and the Lakes Borgne and Pontchartrain basins.

c. Perform a statistical analysis of degrees of protection for the various elements comprising the protection system.

d. Perform physical model tests of wave runup on several existing cross sections using spectral waves from item a.

e. As a separate item, we would like an estimate for development of a 2-D storm surge model for the remainder of coastal Louisiana in conjunction with item b and as a separate study.

These tasks are described further in the following paragraphs. Questions can be referred to Jay Combe at 504-862-2480 or Janis Hote at 504-862-2489. Your response is requested by 17 Dec 93.

3. To begin our reanalysis, we plan to perform an in-house, 2-D wave spectral analysis to determine the wave climate in Lakes Pontchartrain and Borgne. Our analysis will be based on existing topography and hurricane parameters. We plan to use the SHALWV or STWAVE computer programs available in the CMS package. We will need guidance from CERC on selecting the best model to fulfill the intent of the study. We will also require assistance from CERC on development of the PBL wind field model, its use and limitations, and hands on training on the use of whichever model is selected.

4. For the 2-D storm surge study, we would like CERC to develop a grid and 2-D model for Lakes Pontchartrain and Borgne that includes the Rigolets and Chef Menteur Passes and the MRGO and the storage areas adjacent to the lakes. Topographic information surveyed during the last Lake Pontchartrain model study can be used to develop the grid. The model should be calibrated and verified for a high tide non-hurricane event and a hurricane such as Juan or Betsy at gage sites selected by NOD. The model will be used to develop stages in Lakes Pontchartrain and Borgne for the Standard Project Hurricane along several tracks critical to various portions of the project levee. Results from the model should be available as data sets as well as time dependent plots of stages and wind velocity vectors. The model and its results should be accessible to NOD through our PC communication networks and be user friendly enough for our engineers to run the model and browse the output files with a minimum amount of training. Also, the engineer should have the option of altering the storm track and rerunning the model with minimum time and cost.

CELMN-ED-HC
SUBJECT: Cost Estimates for Model Studies of Lake Pontchartrain

5. After design stages and wave heights have been established, we would like to physically model some of the actual cross sections constructed along the project shoreline for wave runup and overtopping during the design hurricane. These flume tests can be performed successively in the same flume; they do not have to be performed simultaneously. Several cross sections will be tested: Jefferson Lakefront, Orleans Lakefront, American Standard Floodwall, Citrus Lakefront, New Orleans East Lakefront, New Orleans East Back Levee, and Chalmette Levee.

6. Using the results of the storm surge model study, we would like CERC to perform a statistical analysis of the degrees of protection of the various levee and floodwall cross sections segments that combine to form the Lake Pontchartrain and Vicinity Hurricane Protection Project.

7. As a separate item, we would like an estimate for development of a 2-D storm surge model for the remainder of coastal Louisiana. The results of this model will be used to determine Standard Project and other design hurricane flood heights for Corps projects along the Louisiana coast.

FOR THE COMMANDER:

W. EUGENE TICKNER
Chief, Engineering Division

COMBE
CELMN-ED-HC

LAURENT
CELMN-ED-H

GRATE
CELMN-ED-S

TICKNER
CELMN-ED

BROUSSARD
CELMN-PD

CELMN-ED-HC 5 NOV 93

MEMORANDUM OF MEETING

SUBJECT: Lake Pontchartrain La. and Vicinity Hurricane Protection Project Wave Design Criteria to be Used in Design of Proposed Breakwaters for Pumping Stations 2 and 3 Jefferson Parish, La.

DATE AND PURPOSE OF MEETING

The meeting was held on 2 Nov 93. The purpose of the meeting was to brief Mr. Tickner about the outcome of discussions that Jay Combe, Janis Hote and Vann Stutts had with Technical Experts at CERC during the week of 25 Oct 93 concerning the subject hydraulic design criteria. Other related topics addressed at the meeting concerned the merits of a suggestion made by Mr. Stutts relative to the need for future lifts on the Jefferson Parish Lakefront levee. List of Attendants is enclosed.

BRIEF SUMMARY OF MEETING

Mr. Combe opened the meeting by handing out the enclosed table of wave heights and wave periods for a range in wind speeds. The table shows computed levee crest elevations for the range in wave heights and associated wave periods. The ACES computer program was used to generate the table. Mr. Combe explained the table and some of the assumptions used in generating it.

After some discussion about the table and the values contained therein, Mr. Tickner asked Mr. Stutts if he agreed with the conclusions that were being drawn from the information presented. Mr. Stutts said that he felt that the values presented were in fact correct for the assumptions upon which they were based. However, he believed that those assumptions may be incorrect. It is his belief that the dynamic nature of the hurricane event did not allow for development of a fully developed sea state and that one could in fact generate a whole new spectrum of "valid" answers depending upon assumptions about boundary conditions. He further stated that the use of wind speeds in excess of the SPH wind speed was inappropriate because we do not have authority to design for a more severe storm than the SPH. He stated that it is true that there are potential hurricane events that could produce a more severe combination of surge and waves than the SPH but that one would have to conclude that the probability of these events occurring, would be extremely rare. Mr. Stutts said that we do not have authority to design for these extremely rare events. He said that when he had run the numbers for the Jefferson Parish Lakefront levee, for the boundary conditions that he used, the analysis showed that the levee crest elevation

could be as low as 14.0 feet n.g.v.d. but that conservatively 14.5 would probably be more adequate.

Mr. Laurent stated that he was of the opinion that a crest elevation of 16.0 feet was close enough and that if we can get our answers to within 1 or 2 feet then we were doing a good job. He stated that we are not dealing with an exact science. Mr. Stutts concurred that there are uncertainties associated with the methodologies and exactitude of the process but that where we can produce a more precise answer and therefore reduce the uncertainties, then we as engineers are obligated to do so and as civil servants we also have the responsibility to get the most protection for each tax dollar expended. He said the degree of protection in Jefferson Parish is established by the east and west return levees/floodwalls that are designed for SPH protection and to raise the lakefront levee to a point where these levee gives more than SPH protection will not provide any additional benefits to the project since the degree of protection in the system is established by the weakest link in the chain, i.e., the return levees/floodwalls.

Mr. Laurent stated that as chief of Hyd & Hydro Branch, it is his decision to make and that he intended to reject the suggestion as he believed that we were close enough with the existing answer. Mr. Stutts said that this call was worth about $10 million and that in his opinion the money would be wasted and could be more effectively spent elsewhere in areas where the protection system is deficient.

The meeting then turned to the subject of the CERC meeting and the wave criteria that was being used to design the project. In short, CERC personnel stated that the 1984 SPM and the ACES shallow water wave forecast curves were at best, first approximations to the answer and that they recommended a more rigorous approach to the design process. They recommended that we consider using the 2-D wave spectral forecast program, SHALWAV or equivalent, to obtain a more "complete" state of the art answer to the wave design problem. They also felt that a sectional physical model might be more reliable in giving values for wave run-up than using ACES or the SPM. The question about storm surge predictions and the storm surge pilot study conducted by CERC for Lake Pontchartrain using the ADCIRC model was briefly discussed with Mr. Tickner. Mr. Stutts stated that the model appeared to give surge elevations in Lake Pontchartrain that are lower than those values that were originally determined by the District in the late 60's. The studies conducted in the 1980's using the WIFM also affirm answers produced by the ADCIRC model. It was pointed out that the predictions of storm surge in the Lake Borgne - New Orleans East Back Levee and Chalmette area gave values higher than those for which the project was being constructed. This coupled with the datum problem, gives cause

for concern when one considers that the floodwalls along the IHNC are designed and constructed with only one foot of freeboard. Mr. Stutts voiced the opinion that given the uncertainties and the seeming skew towards higher storm surges in the Chalmette/ New Orleans East Back area, that it would be in our best interest to consider a complete hydraulic design review of the project using the very latest design tools and storm criteria. Mr. Tickner agreed that all factors that influence the design needed to be looked at.

Relative to the question about the Proposed Breakwaters for Pumping Stations Nos 2 and 3 in Jefferson Parish, it was agreed that the design height for the structure at Pumping Station No. 3 should be elevation + 6.0 feet n.g.v.d. and that we will use an elevation of + 14.0 n.g.v.d. at Pumping Station No. 2. These values will be used to prepare designs and cost estimates for the DM. Mr. Tickner approved the go ahead for the Coastal Engineering Section to proceed with in-house resources to do the 2-D wave study using the SHALWAV program in Lake Pontchartrain. It was agreed that if the wave study showed a substantially different result than was used to design the breakwaters, then we would modify the design during the Plans and Specification for the breakwater. It was also pointed out that if the wave study supported Mr. Stutts contention about the lack of need for future lifts on the Jefferson Parish Lakefront levee then we would need to revisit Mr. Laurent's decision to reject the suggestion. The urgency to make a decision about the suggestion is not great since there are no proposed lifts in the immediate future for this levee.

At this point the meeting was closed with the understanding that CELMN-ED-SP would contact PPMD and set up a meeting with the Project Managers to brief them on this meeting and solicit their opinions as to the best way to bring the Local Sponsor, OLB, into the decision Loop in connection with the disposition of the proposed studies

Encl
as

JANIS HOTE

VANN STUTTS
Civil Engineers

2 Nov 93 Meeting to Discuss Wave Desigm Criteria Lake Pontchartrain, La. and Vicinity Hurricane Protection Project

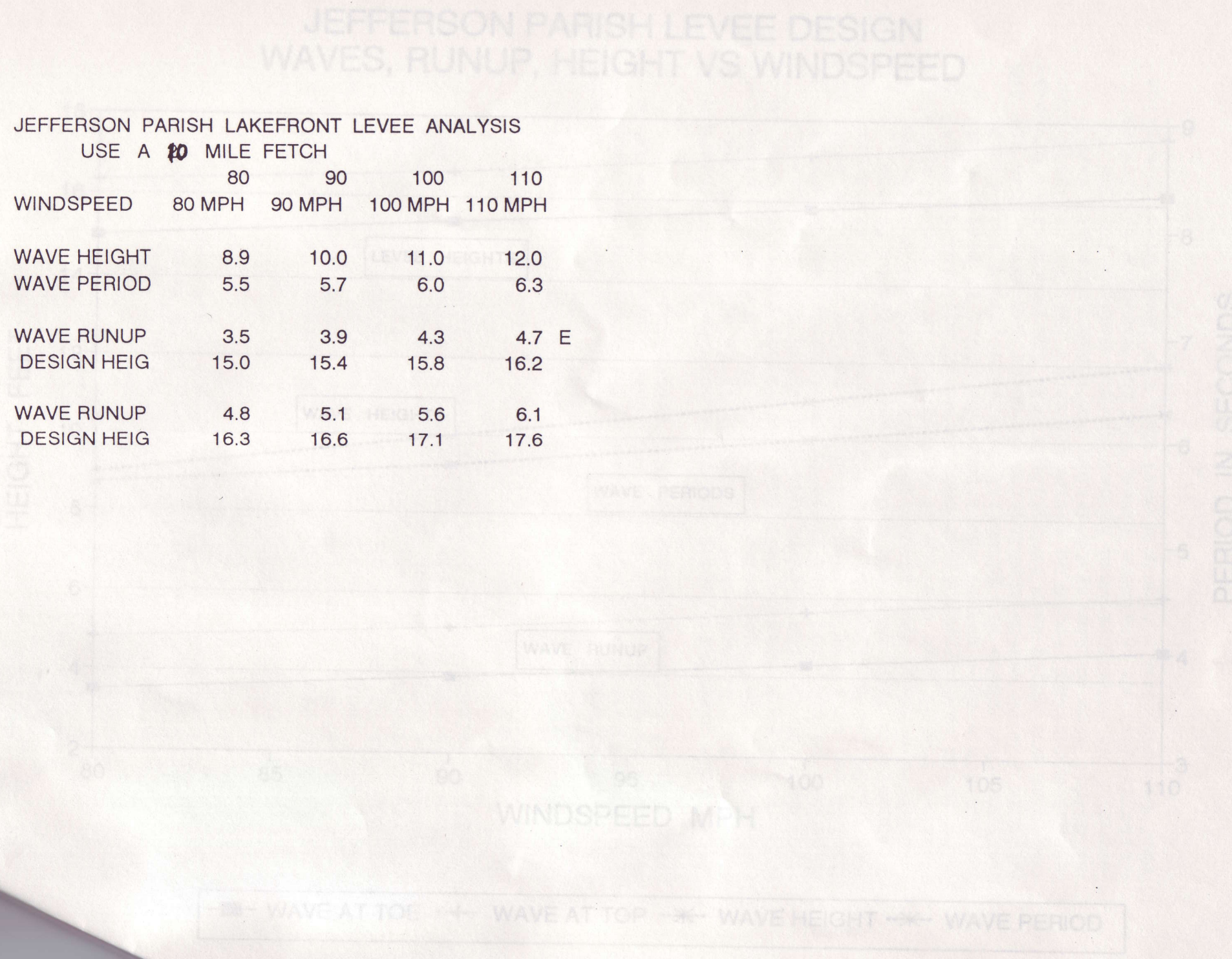
Meeting Attendants

Eugene Tickner	**CELMN-ED**
Authur Laurent	**CELMN-ED-H**
Jay Combe	**CELMN-ED-HC**
Janis Hote	**CELMN-ED-HC**
Ernest Barton	**CELMN-ED-SP**
Vann Stutts	**CELMN-ED-SP**

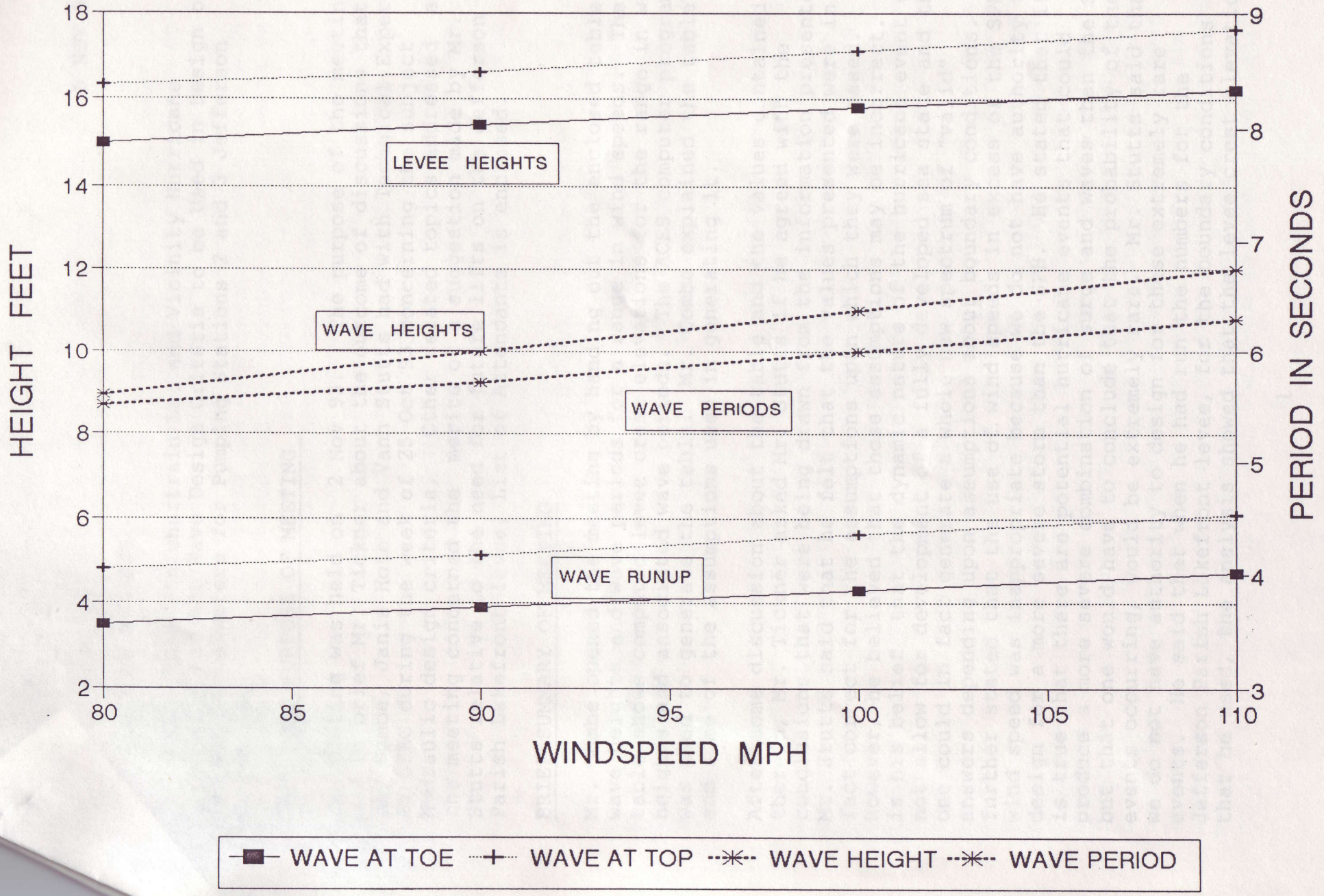
JEFFERSON PARISH LAKEFRONT LEVEE ANALYSIS

USE A 20 MILE FETCH

	80	90	100	110	
WINDSPEED	80 MPH	90 MPH	100 MPH	110 MPH	
WAVE HEIGHT	8.9	10.0	11.0	12.0	
WAVE PERIOD	5.5	5.7	6.0	6.3	
WAVE RUNUP	3.5	3.9	4.3	4.7	E
DESIGN HEIG	15.0	15.4	15.8	16.2	
WAVE RUNUP	4.8	5.1	5.6	6.1	
DESIGN HEIG	16.3	16.6	17.1	17.6	



JEFFERSON PARISH LEVEE DESIGN
WAVES, RUNUP, HEIGHT VS WINDSPEED



WHY ARE WE HERE ?

THERE HAS BEEN A SUGGESTION MADE THAT WE CHANGE THE DESIGN CRITERIA (WAVE FORECASTING AND WAVE RUN-UP) FOR OUR HURRICANE PROJECTS TO REFLECT MORE EXTENSIVE COMPUTER ANALYSIS OF OLD LABORATORY DATA WHICH SUGGESTS A LOWER LEVEE GRADE. THE ADOPTION OF THIS PROPOSAL WOULD CALL FOR A LOWER LEVEE GRADE FOR THOSE SEGMENTS NOT YET CONSTRUCTED TO THE FIRST LIFT ELEVATION AND A SMALLER SECOND LIFT IN OUT YEARS FOR THE ENTIRE PROJECT.

OUR POSITION IS THAT THE POSSIBLE COST SAVINGS ASSOCIATED WITH THE LOWER LEVEE GRADE DESIGN ARE REALLY NEGATIVE BENEFITS BECAUSE RESIDUAL DAMAGES WOULD GREATLY INCREASE FOR SEVERAL GOOD REASONS, TWO OF WHICH ARE KNOWN: (1) ERRORS IN TIDAL DATUMS AND THE NATIONAL WEATHER SERVICE HAS (2) STRENGTHENED THE DESIGN HURRICANE BY AN AS YET UNQUANTIFIED AMOUNT.

TO ADOPT THE SUGGESTION WITHOUT A FULL REVIEW OF ALL DESIGN FACTORS IN EFFECT WOULD LEAVE A SPILLWAY IN THE PROJECT AND CORRESPONDINGLY LOWER THE PROJECT LEVEL OF PROTECTION.

(1) We currently use the original Tidal datum employed at the time Project construction was started i.e, Lake Pontchartrain La & V.C we use 1964 datum. Outfall canal floodwalls are currently being constructed using 1964 datum.

(2) ADCIRC model study showed no difference in original NOS SPH Storm 1966 and 1986 SPH as forces wind speeds and predicted Storm Surges. However ADCIRC model showed that Lake Pont Stages are considerably lower than originally predicted by NOS in the 1950-60 studies.

FACTORS IMPORTANT TO DESIGN OF HURRICANE PROJECTS

* TIDAL DATUMS, HYDROGRAPHIC BOUNDARIES, & COASTAL NAVIGATION CHARTS

* UP-TO-DATE KNOWLEDGE OF HISTORICAL HURRICANE PARAMETERS AND FREQUENCY OF OCCURRENCE

SUITABLE HURRICANE WIND-FIELD MODELS

SUITABLE STORM SURGE MODELS

* WAVE FORECAST AND WAVE RUN-UP MODELS

* TOPOGRAPHIC MAPS

* THESE FACTORS HAVE CHANGED SINCE OUR LAST REVIEW IN 1979.

WHAT HAS CAUSED CHANGE ?

WITH RESPECT TO TIDAL DATUMS, HYDROGRAPHIC BOUNDARIES AND TOPOGRAPHY

A. SUBSIDENCE/COMPACTION OF GEOLOGIC DEPOSITS UNDERLYING PROJECT AREAS IN SOUTHEAST LOUISIANA.

B. EROSION OF SHORELINE AND SEA BEDS IN AREA.

½ meter off Hydrography reduced Predicted Stages

WITH RESPECT TO HURRICANE PARAMETERS AND THEIR NATURAL DISTRIBUTION (FREQUENCY IN NATURE)

A. MORE OBSERVATIONS ADDED TO DATA BASE BETWEEN 1975 AND 1992.

B. BETTER DOCUMENTATION OF GILBERT, HUGO, ETC. SATELLITE AND SEA BUOYS.

WITH RESPECT TO WAVE FORECASTING AND WAVE RUN-UP MODELS

A. BENEFITS OF MODERN FIELD OBSERVATIONS.

B. BENEFITS OF HIGHSPEED COMPUTER ANALYSIS OF WAVE SPECTRUM DATA.

C. LABORATORY RESEARCH.

BENEFITS / PITFALLS TO PROJECT REVIEW

A. CHANGE IN TIDAL DATUMS COULD SHOW PROJECT 0.6 FOOT TOO LOW.
doesn't matter we are still contending to original tidal datum

B. THE ADDITION OF GILBERT, HUGO, ETC., COULD SHOW PROJECT SEVERAL FEET TOO LOW. Not so.

C. THE WAVE RUN-UP CHANGES COULD SHOW PROJECT WAS BUILT 1.0 FOOT TOO HIGH FOR CHOSEN DESIGN HURRICANE.
2' in telephone pond

D. CHANGE IN TOPOGRAPHY / HYDROGRAPHY COULD GO EITHER WAY.
↓ ADCIRC model showed reduced storm surge height with lowering of Bathymetry

MAIL LISTING FOR D. Vann Stutts April 8, 1992

- - Mail - -

April 2, 1992 9:01am MAIL IS -
FROM: C/ Engineering Division Private
TO: D. Vann Stutts
SUBJECT: suggestion

I drafted a memo this morning fwding your suggestion to Comptroller (thru H&H and Wagahoff) with a recommendation that it be referred to LMV for consideration..to include such additional input as the suggestor may wish to provide.

I was not comfortable including those memos you had provided direct to me.

Eugene

3 Dec 1991

ADDITIONAL CLARIFICATION AND THOUGHTS ABOUT SUGGESTION NO.CELN920007

Based on my conversation with Jay Combe on 27 Nov 91, it appears that there is some confusion about my suggestion to use the most recently approved design guidance on shallow water waves to evaluate the need for future levee lifts. Because of this, I offer some additional thoughts on the matter.

There are two components which are needed to establish the design height of a levee that will be exposed to waves. These components are the design storm surge height at the proposed levee location and an estimate of the wave climate at that location. My suggestion indicates that the way we estimate the second component, wave climate, has changed and new guidance suggests that the original design guidance over-forecasted the wave heights and periods. Thus, run-up values computed with those wave heights and periods were grossly over estimated. I am not aware of any guidance that would suggest that our original estimates for the first component, storm surge, are in error. It is true that there have been advancements in the scientific rigor that one can employ in estimating storm surge but there is no evidence to suggest that our original storm surge estimates and the associated stage-frequency curves are in error. If our Hydrology and Hydraulics Branch has reason to doubt the validity of the storm surge component, then they, I believe, are obligated to re-investigate that component also. I might add that it seems strange to me that this issue now surfaces only after my calling into question the wave issue? It would be nice to have confidence in our estimates of the degree of protection afforded by these projects. However, questions about the surge component of the design <u>do not</u> negate the validity of the suggestion about the wave climate.

I think that the reviewer should know that the degree of protection afforded throughout each hydrologic unit of a project should be the same for the unit as a whole. This means that if the current state of construction for a unit is such that portions of the levees in that unit have been raised to say the second or third lift then the remaining portions of the unit needs to be raised to the same level so as to provide a uniform degree of protection in the unit. The whole levee system in the unit would of course have to be at or above the net design grade required by the design storm surge and the run-up computed with the re-evaluated wave climate.

The reviewer should also be informed that the most recent design guidance for forecasting shallow water waves and their periods was used in the design of the Westbank Hurricane Protection Project. Lake Pontchartrain, La. and Vicinity, New Orleans to Venice, La., and Larose to Golden Meadow, La. hurricane protection projects were all designed using TR-4. The Lake Pontchartrain project, was designed to protect against the occurrence of a Standard Project Hurricane, SPH, and each of the hydrologic units in the project, with the exception of Jefferson

and St. Charles Parishes, have most of their final levee lift in place. The St. Charles levee was judged not to be subject to wave attack. Therefore, the only remaining unit where potential saving may accrue is the Jefferson unit. I stated in my suggestion that I estimate that at least half of the remaining lifts in the Jefferson lakefront levee reach can be eliminated. I need to point out to the reviewer that the Jefferson Parish return levees/floodwalls are designed for SPH protection, using the lakes stillwater level plus 2 ft. of freeboard, i.e. no waves. This means that if we insist on completing all of the currently proposed future lifts on the lakefront levee, then we will have actually provided more than SPH protection at the lakefront but will in reality only have SPH protection for the system as a whole. To use a rather worn out phrase, a chain is only as strong as its weakest link. To raise the lakefront levee higher than required for SPH protection is a waste of the tax payers money.

The N.O. to Venice and Larose to Golden Meadow projects are property protection projects, design to protect against the 100 year frequency stage and associated wave climate. In the current program the remaining future levee lifts for N.O. to Venice are estimated to cost about $62 million. If we insist on using the original TR-4 wave heights and periods, all hydrologic units require additional 2nd, 3rd or 4th lifts to achieve the authorized degree of protection. The travesty here is that the local sponsor is in actuality paying for a higher degree of protection than he is being given credit for. I refer to his efforts to satisfy the FEMA requirement for the flood insurance program. The base flood elevations used to set rates and control development under the flood insurance program appears to have been accessed at too high of an elevation because of predicted wave overtopping.

The Larose to Golden Meadow, current program calls for about $35 million in future levee lifts, once the 1st lift of the " D " north levee is in place. For the remainder of this project the current construction status shows that some of the second lift reaches are complete. The remaining second lift reaches will necessarily need to be constructed to provide uniform protection through-out. Although not all of this levee system is subject to wave attack, I believe that an analysis with the current shallow water wave criteria will show that the third lift will not be necessary on those reaches where waves run-up was taken into account in the original designs. The local sponsors for both of these projects should, at the very least, be given the opportunity to make the decision to proceed or not to proceed with future lifts that in essence provide 100 year plus project protection.

It is my opinion that the combined total potential savings for these three projects will be in the range of $30 to $50 million. Given the magnitude of these numbers it is unthinkable to simply sweep the suggestion aside without being given a sound technical basis for rejecting it.

DAVID VANN STUTTS
Civil Engineer

21 Oct 1991

SUGGESTION FOR DESIGN REVIEW OF OUT-YEAR LEVEE LIFTS
FOR NOD HURRICANE PROTECTION PROJECTS

Most of the designs for the New Orleans District's hurricane protection projects were accomplished using hydraulic design methodologies developed in the late 50's and early 60's. Specifically, wave forecast curves contained in the then accepted design standard, TR-4 (1964 edition), overpredicted wave heights and periods for the shallow water case. We know this to be true from comparisons made between TR-4 forecasted waves and those forecasted using the SPM (1973 and 1984 editions) and the A.C.E.S. computer program (1990 edition). Generally, the longer wave periods forecasted by TR-4 produce higher run-ups on protective structures than the shorter periods forecasted by the SPM and the A.C.E.S. program. Our hurricane protection projects are design to protect against wave run-up and overtopping from the significant wave. Since the waves used to design these projects are known to be overpredicted, one can conclude that the net grades established for the design of the projects are higher than they would have been, had the more current methodology been available from the outset. However, we can still make use of the most recent technological advances and wave forecast data by undertaking a complete review of the need for constructing currently programed out-year lifts on those hurricane levees subject to wave attack. A real potential exists for millions of dollars in savings to these projects. For the Lake Pontchartrain project, the Jefferson Parish lakefront levee alone, has out-year lifts totaling more than $ 10 million. If a comprehensive analysis using the most recent design guidance and computer capability were undertaken, I estimate that the resulting designs will show that more than 1/2 of this work can be eliminated.

Critics of this suggestion will say that other factors such as eustatic sea level rise and deltaic subsidence make it necessary to raise these levees even higher than currently proposed. These phenomena were not taken into account when the hurricane projects were designed. I would offer to these critics that without a review of wave runup, we would still have to consider sea level rise and deltaic subsidence. Any remedial measures to counteract these phenomena would be in addition to the effects of wave runup.

As engineers we should use the most rigorous cost effective approach to the design process available to us. Where we are able to quantify to a high level of exactitude then we should do so. In areas of relative uncertainty we need to employ a factor-of-safety, i.e. freeboard. However it would be illogical (certainly unscientific) to say that we used a conservative wave run-up and overtopping approach to account for eustatic sea level rise and deltaic subsidence. We need to be making every effort available to us to quantify the magnitude of these phenomena, so that if necessary informed judgements can be made to account for them in the designs.

David Vann Stutts

DAVID VANN STUTTS
Civil Engineer